

## **Virtual Transects: A Novel Technique for Assessing the Linear Extent of Floating Kelp Beds in Washington State**

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Kelp bed abundance is usually quantified by areal measurements, which are easy to derive from Geographic Information System (GIS) data. However, kelp beds can also be viewed as a feature that is distributed in a linear band along the shore. The characterization of kelp beds as an along-shore feature may be as important as kelp bed area for assessing habitat function. We have developed a novel technique to determine the spatial distribution and abundance of floating kelp as a linear feature. The input data are a vector shoreline and kelp canopy polygons derived from remote-sensing data. The algorithms are written in the C++ programming language. First, the shoreline vertices are densified to 10 meters. This densification value was selected based on a minimum kelp patch size of 40 meters diameter. Next, for each point on the coastline, a 'virtual' transect is extended a specified distance from shore. If this transect intersects a kelp bed, the originating point is assigned a code to indicate that kelp was found offshore. We calculate the length or proportion of shoreline that has kelp offshore, and delineate the spatial distribution and extent of kelp beds along the coastline. Our approach is quite robust to changes in input shoreline resolution as well as variations in methods for determining transect angle. We will compare this linear measure of kelp habitat abundance to areal abundance measures, especially how these measures describe trends over time. Finally, this technique could be used to estimate the abundance of any feature that tends to be distributed linearly along a feature such as coastline or river.

## **Geologic Mapping of Marine Benthic Habitats at Puget Sound, Washington**

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Seafloor morphology and substrate type are two primary physical factors that define marine habitats. Despite many years of study, the nearshore areas of Puget Sound remain largely unknown because of their great extent, difficulty of direct observation, and geologic heterogeneity. Recent advances in marine-survey technology, like acoustic and laser bathymetric systems, now provide detailed imagery that help determine the geographic distribution of benthic habitats. High-resolution mapping, coupled with well designed

geologic and biologic sampling, enable researchers to evaluate ecosystem character and extent on regional and site-specific scales. Such evaluations are central to the delineation and management of Marine Protected Areas. These data also support: 1) the development of circulation models, which are critical to identifying pathways for the movement of sediment, nutrients, and biota, and 2) understanding the response of nearshore environments to dam removal. Examples of seafloor-mapping techniques are presented to demonstrate their utility for ecosystem research. Coordinated efforts by marine geologists and biologists are required to translate the high-resolution imagery into readily useable maps that accurately depict both seafloor geology and biology, and meet the needs of habitat researchers.

## **An Inventory of Washington State's Marine Shorelines using the ShoreZone Mapping System**

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Accurate information on the quality, quantity and distribution of intertidal habitats is important to monitoring and sustaining the health of Puget Sound. The Nearshore Habitat Program of the Department of Natural Resources (DNR) inventories and monitors intertidal habitats as part of the Puget Sound Ambient Monitoring Program. The crucial need for a rapid and consistent inventory of more than 3000 miles of shoreline has led to the completion and distribution of Washington State's ShoreZone Mapping Project.

This poster summarizes the state-wide inventory of Washington's marine shorelines using the ShoreZone Mapping System. This helicopter-based method uses videography with simultaneous audio descriptions by both a coastal geomorphologist and marine biologist. The data were collected between 1995 and June 2000. The resulting GIS data set includes approximately 50 parameters that describe important physical, anthropogenic, and biological shoreline features. Inventory results show spatial patterns in features that are considered by many to be indicators of ecosystem health. The digital data set is available on CD-ROM.

## **Building a Seamless Digital Elevation Model of the Puget Sound Basin**

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The digital elevation model (DEM) of Puget Sound forms the fundamental topographic description of the region from which most, if not all other, geographic information system (GIS) products are derived. Yet for both historic and jurisdictional reasons, DEMs are truncated at Mean Sea Level, making it impossible to model shore and estuary environments in a GIS. The traditional boundary between land and sea governing agencies complicates the integration of bathymetry and topography because there is a general lack of data

overlap at the shoreline and because the elevation products of the NOS and the USGS are developed in two incompatible vertical datums.

We attempt to rectify the vertical datum differences between NOS hydrographic survey data (Mean Lower Low Water) and the USGS 10 meter DEM (NGVD1929) by constructing a correction surface from over 80 tide stations throughout Puget Sound. From the correction surface, we have attributed the DNR shoreline with Mean High Water elevations and use this to re-interpolate the near-shore topography between the NOS bathymetry and the published USGS contours. The resulting DEM reveals limitations in the density of near-shore elevation data, particularly in deltaic environments, but it provides a seamless digital model of the Puget Sound Basin which is uninhibited by artificial boundaries between land and sea.

## **Examples of Application of ShoreZone Mapping Data from the State of Washington**

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The ShoreZone Inventory of Washington includes detailed characterization of approximately 5,000 km of shoreline between the Columbia River mouth and the Canadian border. The data set is suitable for a wide variety of applications including state-wide and regional land-use planning, scientific research and tactical planning for oil spills. This paper provides examples of how the data set can be used.

- Regional summaries of resource distribution can guide protection and restoration. The inventory shows a state-wide occurrence of eelgrass on 30 percent of the state's shoreline, with occurrence as high as 60 percent in northeast Puget Sound and less than 13 percent in southern Puget Sound.
- The ShoreZone Inventory can be combined with freshwater habitat data from the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) to produce a more complete profile of the habitats used by salmonids.
- Biophysical data can be used to select and screen potential monitoring sites. Narrow sand & gravel beaches are the most common shore type in Puget Sound, making them a candidate for monitoring. The data set identifies the location of these sites.
- Predetermined models such as potential oil residence can be used to prioritize oil spill response. In King County, 13 percent of the shoreline has the highest predicted oil residence time.

## **Status Review of Chum Salmon for ESA Listing in Puget Sound**

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In 1994, the Northwest Region of the NMFS received petitions to list chum salmon (*Oncorhynchus keta*) from Puget Sound as threatened or endangered species under the Endangered Species Act (ESA). In response to these petitions and the more general concerns for the status of Pacific salmon throughout the region, NMFS initiated biological status reviews for all species of anadromous salmonids in the Pacific Northwest. In December 1997 the NMFS Northwest Fisheries Science Center published a status review

from the Chum Salmon Biological Review Team (BRT) that described four distinct population segments or evolutionarily significant units (ESUs) of chum salmon: Strait of Georgia/Puget Sound Hood Canal Summer-Run, Pacific Coast, and Columbia River. The BRT reviewed population abundance data and other risk factors for these ESUs and concluded that two (Hood Canal Summer-Run and Columbia River) were likely to become endangered in the foreseeable future. In 1999 summer chum salmon in Hood Canal were listed as threatened under the ESA.

This presentation summarizes both the original information from the 1997 chum salmon status review, and new information on the Hood Canal Summer-Run and Columbia River ESUs received since the listing in the federal register notice.

## **Potential Impacts of Cascadia-margin Earthquakes on the Fraser (Vancouver) and Duwamish Deltas (Seattle)**

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Large earthquakes generated along the Cascadia subduction zone pose hazards to greater Vancouver and Seattle, whose ports are built on the Fraser and Duwamish River deltas, respectively. Although located more than 100 km from the outer coast, the cities remain at risk due to local conditions that increase the potential of earthquake-induced ground failure. The accumulations of loosely consolidated delta sediment are up to 300 m thick and can significantly amplify ground motions. Dynamic motions with site periods vary from 0.2 to 0.5 seconds on the delta margins to 4 seconds in the delta center.

Extensive drilling programs by the USGS, GSC, and other agencies recently have examined the sedimentary framework of these urbanized deltas. The primary objectives were to determine the stratigraphic and geographic distribution of sandy sediment, which is susceptible to liquefaction, and to evaluate the potential impact of earthquakes on the region's industrial and transportation infrastructure. Sand-filled dikes, sills and other paleo-liquefaction features are commonly visually observed and suggest the occurrence of strong ground shaking in the past. Cone-penetration tests (CPT) and standard penetration tests (SPT) were used to characterize potentially liquefiable deposits. The sandy unit of principal concern on the Fraser delta is 8-30 m thick and interpreted to represent a complex of distributary channel sands. The youngest and most liquefiable deposits are located adjacent to the present Main Channel and delta front. Buried channels and laterally continuous layers of sand, probably derived from lahars (volcanic debris flows), also occur on the Duwamish delta. Based on modeled earthquakes, where ground acceleration may significantly exceed 0.2 g, there is a high potential for large strain disintegrative flow failure on the delta front and slope, potentially including the port facilities.

## **A Wide Area Rapid Assessment Technique for Benthic Habitats**

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Offshore geophysical survey methods provide a rapid and cost-effective tool for environmental assessment of coastal zones, estuaries, rivers, lakes, and other water bodies. Mapping of benthic habitat and subsurface geology by Golder Associates Inc. (Golder), is done from small vessels using an integrated combination of side-scan sonars, single or multibeam echosounders, subbottom profilers, underwater video, and the differential global positioning system (DGPS). Surveys conducted to map submerged aquatic vegetation (SAV) (*Zostera* sp. and macroalgae) using solely underwater video can miss important features such as abandoned outfalls, partially buried cables, recreational vessel mooring anchors, and rock outcrops. In addition, video surveys will misrepresent patchy eelgrass conditions as contiguous beds causing erroneous estimates of areal coverage and habitat value. This can cause problems with alignment and site selection and impact mitigation planning. A side-scan sonar survey, integrated with video images to verify species composition and signal interpretation and real-time DGPS for precise positioning, provides a comprehensive high-resolution map of actual conditions over a relatively large area. Data acquisition and post-processing to produce a map of surficial conditions requires considerably less time and effort compared to mapping the same area by scuba diver or with underwater video alone. This poster presents results from recent marine geophysical surveys conducted to map and select a route for a proposed fiber optic cable in the San Juan Archipelago, Washington.

## **Submarine Landslides in Northern Puget Sound: Magnetic Susceptibility Analysis of Piston Cores Collected Near Edmonds, Washington**

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High resolution seismic reflection data suggest that the uppermost 150-200 m of post-glacial sedimentary fill beneath Puget Sound consists primarily of turbidite and landslide deposits. The objectives of this study were a) to obtain long (~10 m) piston cores that would penetrate deeply enough to return samples of the most recent turbidite/landslide deposits and b) to determine the geometry and relative ages of the deposits and their frequency of occurrence. Digital bathymetry data from NOAA were used to select a general study area in the vicinity of Edmonds. Site surveys were conducted using a 3.5 kHz subbottom profiler aboard the University's *R/V Thomas G. Thompson*. Four long (4-9 m) cores were obtained from a variety of morphological provinces extending from Point Wells to the Meadowdale area. Two thick (0.7 and 1.2 m) turbidite sequences from a core 2.5 km north of Edmonds indicate that the shoreline has been unstable during the last 1000 yrs. Understanding the various mechanisms by which the shores of Puget Sound are undergoing continuous modification is important if we are to safely engage in the types of offshore engineering and development—sewer outfalls, port facilities, etc.—that the area's growing population will demand.

## **Pen-raised Fish Attract Orca Whales: An Hypothesis Concerning an Extended Stay of Orca Whales in Dyes Inlet in 1997**

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Orca whales (*Orcinus orca*), resident of waters of the San Juan Islands, Washington, feed primarily on salmon and are occasionally seen in Puget Sound individually or in small groups. In October, 1997, three pods totaling 58 whales appeared in Dyes Inlet. After one day all but 19 Orcas left. These remaining animals stayed an additional 29 days. During this time, it is assumed that the Orcas fed on the Chico Creek Chum salmon (*Oncorhynchus keta*) run. The food requirement for these Orcas was calculated by multiplying the total weight of the 19 animals (mass approximately 56,700 kg) by a daily consumption of 5 percent of their body weight. Based on this estimate, the 19 Orcas would have required 82,215 kg of fish during the 29 days they were in Dyes Inlet. Predicting the Chico Creek 1997 chum run (escapement 4,328 fish) as its historical percentage of Area 10E indicated a shortfall of approximately 63,000 kg between available salmon and the Orca's requirements. We suggest that the Orcas in Dyes Inlet fed on Atlantic salmon (*Salmo salar*) escaped from a pen farm nearby which spilled between 369,000 and 400,000 fish (1,079,325 and 1,170,000 kg) three months earlier.

## **REEF—A Volunteer Fish Monitoring Program in the Pacific Northwest**

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The REEF Fish Survey Project is a volunteer fish-monitoring program developed by the Reef Environmental Education Foundation (REEF). REEF volunteers collect fish distribution and abundance data using a standardized visual method during regular diving activities. Survey data are recorded on preprinted data sheets that are returned to REEF and optically digitized. These data are housed in a database that is publicly accessible on REEF's Website (<http://www.reef.org>). Since its inception in 1993 the REEF program has generated over 25,000 surveys in the Caribbean region. In 1998 REEF expanded to the Pacific Northwest and to date, over 450 surveys have been conducted throughout Puget Sound, the San Juan Islands, and British Columbia. Through a partnership with the Living Oceans Society, a pilot study is currently underway to include invertebrates in the Pacific Northwest REEF methodology. REEF's standardized census method provides a consistency in data collection applied over a wide geographic range. The REEF database represents a valuable tool for marine resource managers and scientists. The database establishes baseline data, provides a taxonomic inventory, and can be used to develop species distribution maps and examine species and community trends. REEF data are currently being used for a variety of assessment and long-term monitoring projects.